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Metrics for Tracking Climate Change Adaptation - A Report to the Los Angeles County Metroplitan Transportation Authority

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METRICS FOR TRACKING CLIMATE CHANGE ADAPTATION

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A Report to the Los Angeles County Metropolitan Transportation Authority

FTA Climate Change Adaptation Pilot Project

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INTRODUCTION AND METHODS

The Urban & Environmental Policy Institute at Occidental College (UEPI) is pleased to transmit to the Los Angeles County Metropolitan Transportation Authority (Metro) a report on metrics for climate change adaptation. The report recommends key metrics that Metro should use to track the progress of the agency's climate change adaptation efforts.

We appreciate that Metro is among the leaders in adapting transit to the realities of a changing climate. We hope that these metrics can help the agency assess how well it is implementing its climate adaptation goals. Metrics can generate a feedback loop between actions and data that can help the agency continue to plan for operating in a changing climate. The result will be a resilient transit system that continues to serve and link Los Angeles County's diverse communities.

While the report is targeted to Los Angeles Metro, the metrics analyzed in the report should also be informative for other transit agencies.

To prepare the report, UEPI first conducted a literature review on metrics and indicators for climate change adaptation by transit operators. Climate adaptation by transit agencies is a new and evolving field, so the scan of the literature did not reveal a set of standard metrics for climate adaptation. It did, however, provide examples of metrics that transit agencies are beginning to use. UEPI also translated common adaptation actions found in the literature into potential metrics. Additional metrics emerged from discussions with Metro staff about the agency's operation.

The metrics fall into four categories: planning, operations, adaptation, and riders. Some of the metrics are binary, providing 'yes or no' answers as to whether a transit agency is taking an action related to climate adaptation. Other metrics require gathering and comparing numerical data.

UEPI generated 109 possible metrics through the literature review, related research and discussions with Metro. Since this amount of indicators would likely be unwieldy to track, we developed criteria to rank the metrics so as to identify a smaller set of priority metrics that Metro and other transit agencies could gather and analyze. Each metric was rated none, low, medium or high for each of five "core criteria" and six "multiple benefit criteria." The six core criteria are: criticality, severity, equity, feasibility, cost and best practice. The five multiple benefit criteria (so called because they measure whether a metric provides information that would help an agency address other elements of their climate change agenda) are: climate, visibility, participation and governance, design, and mitigation.

Points were summed to provide a score for each metric. Core criteria granted twice the points of multiple benefit criteria. High, medium, and low in a core criteria earned 6,4, and 2 points and earned 3,2 and 1 points in a multiple benefit criteria. Each metric could therefore receive up to 54 points.

Based on the ratings, UEPI strongly recommends that Metro track the 20 highest ranked metrics- all those metrics rated 35 or above. We provide a summary, a description of what data needs to be collected, and a justification and recommendations for each of these twenty top priority metrics. An additional 19 metrics were rated 34 or 33. We categorize these 19 as 'recommended' metrics which Metro should track if they have the capacity to measure more than 20 metrics. The agency may also choose to track some of the additional 70 metrics ranked below 33 if these metrics are particularly relevant to the agency's climate adaptation efforts.

CRITERIA USED TO RANK METRICS

Criteria	Summary	Rationale
criticality	Does metric inform risks to critical asset?	Protect critical assets
severity	Does metric inform anticipated significant risks to assets and/or riders?	Adapt to severe impacts
equity	Does metric inform impacts on transit-dependent and diverse communities/ riders?	Protect most vulnerable riders/ communities
feasibility	Is it easy or difficult to gather this data?	Understand what needs to be done to track metric
cost	Is metric cost effective to implement?	Prioritize higher impact, lower cost metrics; ensure budget is adequate to gather important data
best practice	Is metric gathered by other transit agencies or related climate adaptation efforts?	Learn from literature review and peers; be able to share data and methods
climate	Does data add to understanding of local weather/ climate?	Improve access to real time weather data and climate change forecasting
visibility	Does metric help inform public on need for climate adaptation?	Expand awareness of climate change, need for adaptation, and agency efforts
participation and governance	Does metric involve employees and/or staff and/or improve ability to coordinate actions	Broaden involvement in and coordination of adaptation efforts
design	Does metric inform system design as well as operations?	Help create resilient, widely-used system
mitigation	Does metric inform mitigation as well as adaptation?	Help reduce emissions and mitigate impacts of climate change

PRIORITY METRICS

1. Have impacts on riders been analyzed? (43 points)

Summary: Has the agency analyzed how climate change may impact the behavior, health and comfort of its riders?

Metric data: Yes or no. (Agencies may also want to track the frequency of their analysis and how many riders were interviewed as part of conducting the analysis).

Justification and recommendations: The chief mission of transit agencies is to provide convenient and safe mobility options to persons who use the system. Climate change can impact this mission by interfering with or influencing how a transit agency operates its system and by influencing the behavior of users. While agencies cannot control how riders react to a changing climate or extreme weather events in the same manner that an agency can adjust its operations or technology, it is critical to consider ways that climate change may influence users' actions and attitudes. This will ensure that climate adaptation plans and actions help protect the health and safety of riders and help maintain or expand ridership in a changing climate. A transit agency should analyze impacts on riders as part of conducting a climate change vulnerability assessment, and may want to supplement this analysis with regular surveys, interviews or focus groups. Metro gathers information on customer satisfaction on a regular basis.[1] This information includes the way that riders get to their stop of station, how long it takes them to reach their stop/ station and how long they typically wait for their bus or train to arrive. This data provides useful information on whether and how system users are exposed to sun, rain or flooded roads. The survey asks riders if they have cell phones/ smart phones, which can help determine if extreme weather alert could help users. A question on whether riders feel safe waiting for and riding the system could be adapted to ask about the rider's comfort. The agency could also query riders about whether they change their behavior when the weather is extreme, and ask customers if their stop or station has adequate shade. These questions can be added to customer surveys or gathered by some other method.

2. Has vulnerability assessment been conducted? (39 points)

Summary: Has the agency assessed its system's vulnerability to climate change impacts that are anticipate to develop in its area of service?

Metric data: Yes or no. (Agencies may also want to track how long it has been – in years - since they last conducted or updated their vulnerability assessment.)

Justification and recommendations: A vulnerability assessment lies at the heart of planning and preparedness for climate change adaptation. Conducting a vulnerability assessment allows an agency to familiarize themselves with anticipated weather and climactic changes; to analyze how these changes may affect their systems and operations; and to identify the most vulnerable assets. Understanding these likely impacts sets the groundwork for identifying and prioritizing adaptation actions to reduce vulnerability and increase the resilience of both physical infrastructure and operational systems. As more transit agencies perform vulnerability assessments, best practices will continue to evolve. Metro should keep abreast of the state of the art in climate vulnerability assessments so that it can periodically update and fine-tune its own assessment.

1 http://www.metro.net/board/Items/2012/10_October/20121010OtherSectorWESItem4.pdf

3. Mean Distance Between Failure (MDBF) for buses by temperature and geography (39 points)

Summary: How does the number of miles that buses travel, on average, before they suffer mechanical problems that require the bus to be taken out of service for repairs, vary by the temperature at the time of year of break-down and by the average temperature of the area that bus broke down in?

Metric data: Average number of miles that buses traveled between breakdowns, analyzed and arranged by A. the high temperature of the day (or average temperature of the week or month); and B. by the average summer high temperature of the agency's sub-geography.

Justification and recommendations: Metro's 2012 Climate Action and Adaptation Plan identified "Fleet breakdowns and maintenance during periods of extreme heat" as the most significant adaptation challenge facing its bus operations. [2] Tracking MDBF, which is a standard industry measurement of rolling stock reliability and performance, by temperature and geography, will allow Metro to determine if and how breakdowns are impacted by high heat. It will provide a baseline and ongoing data with which to measure the effectiveness of maintenance approaches to cope with expected increases in temperature. To track potential increases in breakdowns from both short-lasting heat waves and longer trends, we recommend analyzing breakdowns by both individual daytime high temperature of the region and by the average high temperature of weeks or months. We also recommend that Metro track MDBF by Bus Divisions and/or Los Angeles County Service Planning Areas, and calculate the average summer time high temperature of these sub-geographies.

4. Have adaptation actions been prioritized? (38 points)

Summary: Has the agency prioritized potential adaptation actions that have been identified through a vulnerability assessment, climate action plan, or other climate adaptation planning?

Metric Data: Yes or No.

Justification and recommendations: Climate adaptation planning for a medium to large size transit system will identify a range of expected impacts and vulnerabilities and a range of actions that an agency can take to adapt to anticipated impacts. To help minimize disruptions to transit service and to contribute to more resilient communities, agencies should prioritize those adaptation actions that are most likely to effectively preserve and improve operations. Prioritization of adaptation actions can be performed as part of an agencies climate planning, ideally in a formal climate action plan that includes a vulnerability analysis. Agency staff and/or consultants preparing plans can use criteria such as criticality, severity, cost, effectiveness, and equity to rate and prioritize from among the full set of identified actions. Metro should ensure that prioritized actions receive appropriate funding and implementation.

5. Have vulnerable assets been mapped with transit dependent and low-income populations? (37 points)

Summary: Has the agency mapped assets that are considered to be especially vulnerable to climate impacts with the demography of its service area, especially for low income, transit-dependent populations?

Metric Data: Yes or No.

2 http://www.metro.net/projects_studies/sustainability/images/Climate_Action_Plan.pdf

Justification and recommendations: Important steps in assessing a transit system's vulnerability to climate change involve potential weather and climactic changes; analyzing how these changes may affect their systems and operations; identifying the most vulnerable assets, and identifying and prioritizing actions to address threats to the system. Once the most vulnerable assets are identified, mapping these assets overlaid with a map of low-income, transit-dependent populations can add an important equity dimension to planning climate adaptation. Vulnerable assets that serve populations that are transit dependent are A. likely to be heavily used; and B. are important resources for populations vulnerable to climate change impacts because they are less likely to own cars or to have financial resources that would allow them to easily evacuate, to afford to miss work, etc. Metro should map its vulnerable assets with areas with high rates of poverty and low rates of car ownership to identify assets that are significant both from an operational perspective and a human needs and equity perspective.

6. Number of injuries/ medical emergencies to workers and riders by temperature and rainfall (37 points)

Summary: Track injuries and medical emergencies sustained on the system and analyze the numbers by temperature and by rainfall.

Metric Data: Injuries and medical emergencies sustained by workers and riders. Compare average number of daily medical incidents to average number of incidents on extreme heat days (Metro should adopt a definition of extreme heat for the purposed of these calculations in which temperature exceeds 91.4 degrees in downtown Los Angeles.)
Also compare average medical incident rate to days with heavy rain, defined as precipitation falling at .3 inches per hour or above.

Justification and recommendations: Higher heat[3] and increased precipitation[4] are anticipated to be two of the most significant climate impacts in the Los Angeles region. These changes to weather may pose threats to the health and safety of transit users and workers. Comparing average rates of injuries and other medical incidents with rates of such incidents on very hot days and days with heavy rain can help identify trends. If there is an increased rate of health issues reported on hot or wet days, Metro should identify strategies to minimize risks. Metro may also wish to track the **types** of injuries that occur on very hot or wet days to see if trends, and reduction strategies, emerge.

7. Does agency have overheating standards for public transport facilities and rolling stock? (37 points)

Summary: Are there design and operating standards intended to prevent and mitigate overheating in facilities or buses and trains that could cause equipment failure or discomfort , negative health impacts, or inconvenience to passengers or employees.

Metric Data: Yes or No.

Justification and recommendations: Increasingly hot weather poses challenges to the operation of equipment on buses and trains and in stations, bus yards and other facilities. Standards to prevent and mitigate the effects of overheating can help ensure more reliable and safer operations. Metro's design, procurement and operating standards should seek to ensure that engines, air conditioning and other critical systems

3 "Mid-Century Warming in the Los Angeles Region." http://c-change.la/temperature/

4 http://www.metro.net/projects_studies/sustainability/images/Climate_Action_Plan.pdf

function in high heat environments. Rolling stock and facilities should also be designed and operated so that customers and employees are comfortable during periods of high heat.

8. Ongoing and regularly convening team tasked with implementing climate adaptation plans. (37 points)

Summary: Does agency have a team of staff charged with implementing action items from climate adaptation plan (or plans) that the agency has adopted?

Metric Data: Yes or No.

Justification and recommendations: Climate adaptation plans need to be implemented to achieve the benefits of planning: forethought, prioritization, avoidance of harm, creation of a more resilient and effective transit system. Because most plans will touch upon actions that involve multiple aspects of operations, finance, customer relations, etc., Metro should establish a team of staff with responsibility to oversee implementation of adaptation plans. This team should have authority from the Board and CEO to coordinate actions and to ensure there is feedback between implementation steps and future information gathering and planning.

9. Percent of climate adaptation recommendations/ actions from adopted plans implemented (37 points)

Summary: What percent of climate adaptation action items from Climate Change plans that agency has adopted have been implemented?

Metric Data: Agency can keep track of implementation of climate change adaptation action items using three categories: 1. Implemented; 2. In process of being implemented; and 3. Not yet implemented.

Justification and recommendations: In order to meter progress in implementing climate change adaptation plans, agencies should keep track of how many action items have been implemented over time. A checklist of climate adaptation commitments and recommendations contained in adopted plans should be maintained, so that implementation or lack of implementation of each can be tracked. We recommend that Metro task the team responsible with implementing climate adaptation efforts to track the agency's progress. Metro might also explore incorporating such progress tracking into annual reports on environmental performance.

10. Capacity to monitor weather and temperature conditions in real time at key locations in service area (36 points)

Summary: Can the agency monitor temperature and precipitation in real time at key locations in the service area, or create partnerships to receive real time data from organizations with weather monitoring equipment?

Metric Data: Yes or No.

Justification and recommendations: High heat days and extreme precipitation events pose risks to transit operations and customers. Tracking weather locally can help identify weather episodes and local stresses and trigger adaptation actions at stations and other facilities. Monitoring weather also allows agencies to calculate climate adaptation metrics that rely on temperature and precipitation data. Metro should measure temperature and precipitation at its critical assets. In addition, the agency should measure this weather data

in at least one facility per Bus Divisions and/or Los Angeles County Service Planning Areas.

11. Extreme weather impacts on service delays and cancellations (36 points)

Summary: Does the agency experience more service delays and cancellations during high heat days and/or heavy rain?

Metric Data: Compare average number of daily service delays and cancellations to average number of service delays and cancellations on extreme heat days (days on which temperature exceeds 91.4 degrees in downtown Los Angeles) and days with heavy rain, defined as precipitation falling at .3 inches per hour or above.

Justification and recommendations: Equipment failures and facility closures from extreme weather may disrupt service. To understand the extent of the disrupting impact of a changing climate, agencies can compare baseline rates of service delays and cancellations with rates of these problems that occur on very hot days and days with high precipitation. Understanding the correlation, if any, between temperature and precipitation and service delays and cancellations will help agencies prepare for extreme weather days by preparing additional capacity, increasing preventive maintenance, etc. Metro should track service delays and cancellations in order to compare rates of service challenges on high heat days and days with heavy rain.

12. Percent of Metro facilities and vehicles with cool roofs (36 points)

Summary: What percentage of facilities have cool roofs and what percent of vehicles have cool roofs or cool roofs and shells designed to reflect sunlight so as to lower the interior and surrounding temperature.

Metric Data: Number of buildings owned, leased and/or operated by the agency with roofs with solar reflectance index of at least .70 for low slopes or .25 for steep slope, divided by total number of buildings and owned, leased or operated by agency. Number of buildings owned, leased and/or operated by the agency with roofs with solar reflectance index of at least .78 for low-slope or .29 for steep slope, divided by total number of buildings and owned, leased or operated by agency. Number of vehicles owned, leased and/or operated by agency with white or silver roofs divided by total number of vehicles. Number of vehicles owned, leased and/or operated by agency with white or silver roofs **and** shells divided by total number of vehicles.

Justification and recommendations: Cool roofs reduce the interior temperature of buildings[5] and cool roofs/ shells do the same for vehicles.[6] This can make customers and staff more comfortable and reduce negative health impacts from overheating. Equipment will also come under less stress, reducing failures, service delays and maintenance and replacement costs. Cooling structures and vehicles will improve fuel efficiency and reduce energy use and greenhouse gas emissions by power plants. Metro should install and retrofit cool roofs and shells on buildings and vehicles to achieve these localized benefits and also to model and encourage broader use of cool surfaces. Models predict that Installing cool roofs, cool pavements, and trees over 30 percent of the surface of the Los Angeles basin would lower the outside air temperature by about 5°F, reducing the expected negative impacts of high heat. To help inspire a broader adoption of cool surfaces, Metro should publicize its own cool roofs through signage on buildings or vehicles or other educational efforts.

5 http://heatisland.lbl.gov/coolscience/cool-science-cool-roofs

6 http://heatisland.lbl.gov/sites/heatisland.lbl.gov/files/Cool_cars_final_LBNL_project_report_v015_2011-08-08.pdf

13. Does agency conduct regular climate planning updates? (36 points)

Summary: Does the agency conduct regular climate planning updates to incorporate new climate change information, the results of adaptation efforts, and best practices into existing adaptation plans?

Metric Data: Yes or No. (Potentially also measure how long it has been since last update to climate action and adaptation plan)

Justification and recommendations: The science of climate change and the policy tools available to adapt to climate impacts are continuously changing. Metro should stay informed of the latest information on how climate change is expected to impact their region, and learn from the best practices of other agencies engaging in adaptation efforts. Metro should also measure and take lessons from its own climate adaptation programs and policies. To enable this learning, growth and refinement in climate adaptation, Metro should update its climate adaptation plans regularly.

14. Are climate adaptation indicators tracked in agency's Environmental Management System and/or Asset Management System? (36 points)

Summary: Does the agency track climate change metrics such as vulnerabilities and actions taken for adaptation of assets in existing systems that track environmental performance and/or the status of assets?

Metric Data: Yes or No

Justification and recommendations: Tracking and quantifying climate adaptation efforts can help assure that an agency is effectively responding to the risks posed by climate changes. Tracking climate adaptation metrics or indicators should be mainstreamed into agency practices and structures where possible. Data on climate adaptation can be slotted into existing information management systems such as environmental management systems and/or asset management systems. Agencies should review and plan how best to capture and track climate adaptation relate metrics in existing management systems. We recommend that Metro should draw upon the report on climate adaptation and its environmental management system prepared by First Environment to undertake this integration.

15. Number of rail kinks/ buckling by temperature and by heat island areas (35 points)

Summary: Do the number of rail kinks or buckling increase on high heat days and/or in areas that have been identified as urban heat islands?

Metric Data: Average number of rail kinks or buckling per day compared to average number of rail kinks or buckling on high heat days (above 91.4 degrees in downtown Los Angeles.) Average number of or rail kinks or buckling per mile per year of track in areas identified as urban heat islands compared to average number of rail kinks of buckling per mile of track in areas identified as not being urban heat islands.

Justification and recommendations: High temperatures can warp or otherwise damage tracks used by above ground rail. Tracking whether increased high temperature leads to more track warping can help agencies predict disruptions from climate change and better design and maintain rail systems to minimize disruptions. Metro should track damage to tracks on high heat days compared to other days of the year. Urban heat island are urbanized areas in which increased permeable surfaces lead to more retention of the sun's energy, leading to air temperatures that can be up to 5 degrees F higher during the day an up to 12

degrees F higher at night.[7] To determine how increased heat from climate change can interact with urban heat islands in its service area, Metro should seek to identify maps of heat islands in Los Angeles County and compare rates of rail bucking in these areas with rates in areas of service that are not classified as heat islands.

16. Number of technical advisors and members of the broader community included in climate adaptation team (35 points)

Summary: How many individuals who are not agency employees are on the climate adaptation team or on a public advisory committee linked to the team?

Metric Data: number of persons on climate adaptation team or an advisory committee to the team who are outside technical consultants or representatives of partner organizations or the public.

Justification and recommendations: An agency's climate adaptation team can benefit from outside technical expertise, partnerships, and public involvement. Metro should include outside stakeholders with expertise in climate change or adaptation as well as public representatives on its climate adaptation team. If it is useful to separate advisory roles from inside, decision-making roles then the agency can establish an advisory committee to the team.

17. Do agency design standards consider climate adaptation? (35 points)

Summary: Do the design standards that the agency uses to set physical and performance parameters for new lines, facilities, and rolling stock incorporate climate adaptation goals?

Metric Data: Yes or no.

Justification and recommendations: Climate change adaptation for public transit involves shaping and "ruggedizing" transit systems so that they perform well under expected future climatic conditions. Design standards are an on of the important ways that agencies mandate the parameters of new infrastructure. It therefore makes sense to include climate adaptation goals in design standards so that new transit infrastructure is built to withstand and to be resilient in the face of high heat, major precipitation, sea level rise, or other climate change impacts. Metro incorporates environmental criteria, including some related to heat, climate and energy, in its design standards. The agency should continue to update design standards as its climate adaptation goals evolve.

18. Has agency designated evacuation routes? (35 points)

Summary: Does the agency have emergency evacuation plans with designated routes, including pick up and drop off points, that could help protect passengers, staff and the general public during extreme weather emergency?

Metric Data: Yes or No.

Justification and recommendation: Climate change is expected to contribute to more severe weather episodes in the future.

Precipitation and sea level rise could lead to flooding and increased heat may be associated with more

7 http://www.epa.gov/hiri/resources/pdf/BasicsCompendium.pdf

severe fires. In the event of a weather emergency, public transit has a responsibility to ensure the safety of its users and staff. Transit can also be mobilized to evacuate or otherwise transport the broader population (residents who were not using transit when a disaster strikes). To deal with potential disasters that may be intensified by climate change, Metro should plan how its system can be evacuated- and plan how the system can be mobilized to help evacuate communities or the entire region.

19. Progress in reducing vulnerabilities based on meta-analysis of climate adaptation indicators. (35 Points)

Summary: Annual progress that the agency made towards achieving its climate adaptation goals and reducing its vulnerabilities to climate change, based on meta-analysis of indicators.

Metric Data: Measure how all metrics change over time. Calculate overall progress by averaging percentage improvement (or decline) in trends. Yes/ No metrics can count as 100 percent/ 0 percent. Because Yes/No metrics will show large swings in positive or negative direction, agency should also calculate average progress just of all numerical metrics.

Justification and recommendations: Climate change adaptation efforts and metrics cover a range of goals and topics. Measuring individual metrics will focus attention on particular aspects of climate change risks or adaptation implementation. It is also important to focus on the big picture of overall progress towards a successful climate response. One way to measure overall progress is to aggregate changes in multiple metrics. Metro should track changes in metrics annually and aggregate shifts to provide a rough estimate of progress. This numeric meta-analysis of change should be accompanied by additional quantitative and qualitative analysis of progress that Metro has made and challenges that the agency faces.

20. Funding needed and provided to implement climate adaptation (35 points)

Summary: How much annual funding is needed to implement climate adaptation plans adopted by the agency, and how much funding has been budgeted for these actions?

Metric Data: Funds required annually to implement climate adaptation actions contained in plans adopted by the agency, compared to annual funds budgeted by the agency for these purposes.

Justification and recommendations: Funding for climate adaptation actions is a sign of an agency's commitment to implementing its climate adaptation goals. Metro should track the funding that is required to implement adaptation efforts and how much money has been provided and spent on implementation.

OTHER RECOMMENDED METRICS

Metric	Score
Percent of agency's policy implementation processes that consider climate	34
Percent of all stations and lines assessed in climate vulnerability assessment?	34
Most vulnerable assets identified Y/N?	34
Percent of key assets with on site weather monitoring	34
Percent insurance premium or bond rates spread for operations/ construction that are vulnerable to climate change vs.	34
Percent of facilities with bioswales or other natural stormwater management systems	34
Critical assets identified Y/N?	33
Percent of critical assets assessed?	33
Percent of extreme weather days vs. percent of normal days with power outages and catenary line complications	33
Are the costs of severe weather events being tracked (for federal disaster aid or otherwise) Y/N?	33
Is there a cost code associated with extreme weather so employees can mark down overtime, repairs etc as weather/ climate related Y/N?	33
Percent of climate implementation team participants authorized to make changes recommended by team in the adaptation planning process.	33
Does agency utilize flood maps to determine facility design parameters such as drainage Y/N?.	33
Does agency's asset management system measure heat and flood vulnerabilities for each asset Y/N?	33
Percent of bus stops with shade	33
Does agency have policies to modify construction schedules and labor practices to protect workers from high heat Y/N?	33
How many people can the agency evacuate in the event of a weather emergency	33
Percent of weather-related service delays/ cancellations that occur in areas with above average transit-dependent populations.	33
Does agency publish regular reports or updates on climate adaptation efforts Y/N?	33

OPTIONAL METRICS

Metric	Score
Does agency have a climate change preparedness team Y/N?	32
Percent of relevant divisions/ department actively represented on team	32
Does agency collaborate with partner agencies, jurisdictions and organizations on climate adaptation Y/N?	32
Percent of stations and stops with drinking water source	32
Does agency have emergency procedures for high heat days, significant rain/ flooding events, and service interruptions Y/N?	32
Percent of passengers who can be moved by alternative modes if one or more rail lines are closed by extreme weather?	32
Do agency's environmental impact assessments and/or related documents identify the potential for disproportionate impacts to impacts to minority, low income and disadvantaged populations from potential climate impacts Y/N	32
Number of staff tasked with implementing climate adaptation actions.	32
Have major barriers to incorporating climate adaptation into implementation processes/ tools been identified Y/N?	31
Is a regional climate model available to better determine local impacts of climate change. Y/N?	31
Percent of service area covered by regional climate model	31
Percent of extreme weather days vs. percent of normal days with interruptions in telecommunications	31
What is the extra cost of extreme weather vs a baseline in $ and as percent of operating budget?	31
Loss in revenues from lower ridership on extreme weather days	31
Number of other collaborations	31
Has agency mapped urban heat islands across service area (or have access to map) Y/N?	31
Percent of metro properties with on site energy generation	31
Does agency have back up plan for failure of electric grid Y/N?	31
Percent of transit dependent service area population lives within convenient walk of train station or frequent bus route	31

Metric	Score
Participation rates of public or advisory members in its internal climate change adaptation team or committee meetings	31
Percent increase in repair and replacement costs from accelerated reduction in state of good repair due to wear of extreme weather	30
Are savings from adaptation being measured/ calculated Y/N?	30
Percent of engineering standards that include tolerances for extreme weather events at the upper bounds of climate change projections	30
Percents of above ground assets, critical assets, and vulnerable assets in urban heat islands	30
Percent of urban heat islands in service area with above average and majority transit dependent populations	30
Percent of stations with capacity and efficiency of pumping and drainage systems to cope with flooding scenarios based on future precipitation and sea level rise projections	30
Have these procedures been evaluated based on their performance in a real world weather emergencies Y/N?	30
Percent of critical and vulnerable facilities with site specific emergency plans.	30
Has agency conducted a cumulative impact analysis of climate change on the public, especially on the most vulnerable populations Y/N?	30
Percent of residents living within walking distance of transit stations and/or high quality bus corridors	30
Percent of stations with joint development plans, land use plans, and/or MOUs to increase density of housing and/or employment near station site	30
What is 'resolution' of RCM? (size of grid squares)	29
Number of real time monitoring stations	29
Ratio of monitoring stations/ service area in square miles	29
Has agency developed adaptation timeline for updating design and engineering standards Y/N?	29
Percent of assets considered to have significant vulnerability to heat	29
Percent of assets considered to have significant vulnerability to flooding	29
Percent of rail stations, bus yards and other critical facilities with back- up generator capacity	29
Percent of rolling stock that is standing reserve available to cover broken down vehicles?	29

Metric	Score
Minimum level of back-up generator capacity to allow rail and bus operations for 24 and 48 hours.	29
Percent of stations and facilities with required level of back up generating capacity	29
Does agency have demographic analysis of its service area and ridership Y/N?	29
Percentage of stations with clean mobility centers	29
Does agency request, collect, analyze and publish recommendations from public on climate change adaptation? Y/N	29
Is there a record of historical weather patterns for the service area Y/N?	28
Number of memoranda of understanding with partners	28
Percent of design and procurement standards for equipment and vehicles that require items to meet future climate conditions.	28
Percent increase in power and fuel consumption on hot days vs. normal days	28
Are there communication channels to alert public about weather-related delays, cancellations, etc Y/N?	28
Have transit dependent and vulnerable populations been identified and/or mapped using established methods Y/N?	28
Has agency surveyed riders on how their travel patterns change during high heat or heavy rain Y/N?	28
Number of stakeholders/ members of public engaged per year	28
Percent of service area covered by weather records	27
Percent foliage coverage at metro stations	27
Does agency have timeline for adaptation efforts to reduce temperature at stops and stations Y/N?	27
Percent of Metro's power generated from onsite renewable energy production	27
Percent difference in frequency of stormwater management equipment maintenance at facilities with high flood risk vs typical facility.	27
Have these communication channels been tested and evaluated Y/N?	27
Amount of money saved based on implemented preparedness action	27
Have complete range of implementation tools that Metro possesses been identified Y/N	26

Metric	Score
Percent savings for comparable extreme weather events with adaptation vs. without adaptation	26
Does agency use utilize the same climate projections/ models as partners Y/N?	26
Does agency capital and/or operating budget have category for climate adaptation or category into which adaptation funding can fit Y/N?	26
Percent of bus stops with seating	25
Records kept of outreach and numbers of stakeholders/ members of public engaged on climate adaptation in person and on-line Y/N	25
Percent of stormwater managed by agency that is managed by natural systems	24
How many years do weather records go back?	23
Minimum level of compressed natural gas reserves to power 50% of bus fleet for one week	23
Percent of this reserve natural gas currently held and available by agency	23
Has agency identified mechanism for inter-agency coordination in place for other purposes that could be expanded to target climate change adaptation Y/N	21

APPENDIX 1:
METRICS RATED FOR EACH CRITERIA

Metrics: Planning

	Have complete range of implementation processes that Metro possesses been identified Y/N	Percent of implementation processes that consider climate	Have major barriers to incorporating climate adaptation into implementation processes/ tools been identified Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)			
criticality	low	medium	medium
severity	low	medium	medium
equity	low	medium	medium
feasibility	medium	high	medium
cost * (points reversed)	low	low	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)			
best practice	medium	low	medium
climate	low	medium	low
visibility	low	low	medium
participation and governance	high	medium	medium
design	low	medium	low
mitigation	medium	medium	medium
Score	**26**	**34**	**31**

Metrics: Planning

	Has vulnerability assessment been conducted? Y/N	Critical assets identified Y/N?	Percent of critical assets assessed?	Percent of all stations and lines assessed?	Most vulnerable assets identified Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	high	high	High	medium	medium
severity	high	medium	medium	low	high
equity	medium	low	low	high	medium
feasibility	medium	medium	high	high	medium
cost * (points reversed)	high	medium	low	low	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	high	high	medium	medium	medium
climate	medium	medium	low	low	medium
visibility	high	medium	Low	medium	medium
Participation and gover-nance	high	medium	medium	medium	medium
design	high	high	medium	medium	high
mitigation	medium	low	low	low	low
Score	**39**	**33**	**33**	**34**	**34**

Metrics: Planning

	Impacts on riders analyzed Y/N?	Overlay of most vulnerable areas and assets with transit dependent and low-income populations Y/N?	Adaptation actions prioritized Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)			
criticality	high	medium	high
severity	high	medum	high
equity	high	high	medium
feasibility	medium	high	medium
cost * (points reversed)	medium	low	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)			
best practice	medium	medium	high
climate	medium	low	medium
visibility	high	high	medium
Participation and gover-nance	high	medium	medium
design	high	medium	high
mitigation	medium	low	medium
Score	**43**	**37**	**38**

Metrics: Planning

	Is a regional climate model available to better determine local impacts of climate change. Y/N?	Percent of service area covered by regional climate model	What is 'resolution' of RCM? (size of grid squares)	Is there a record of historical weather patterns for the service area Y/N?	Percent of service area covered by weather records
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	low	low	low	low	low
severity	high	medium	high	high	medium
equity	medium	medium	low	low	medium
feasibility	medium	high	medium	medium	high
cost * (points reversed)	high	low	low	low	low
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	medium	low	low	high	low
climate	high	high	high	high	high
visibility	medium	low	low	medium	low
Participation and gover-nance	medium	low	low	medium	low
design	medium	low	low	low	low
mitigation	medium	medium	medium	low	none
Score	**31**	**31**	**29**	**28**	**27**

Metrics: Planning

	How many years do weather records go back?	Is there capacity to monitor weather and temperature conditions in real time at key locations in service area Y/N?	Number of real time monitoring stations	Ratio of monitoring stations/ service area in square miles	Percent of key assets with on site monitoring
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	none	medium	low	low	medium
severity	medium	high	medium	low	medium
equity	none	medium	low	medium	medium
feasibility	high	medium	high	high	medium
cost * (points reversed)	low	medium	low	low	low
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	low	medium	low	low	low
climate	medium	high	medium	high	high
visibility	low	medium	medium	low	medium
Participation and gover-nance	low	medium	low	low	medium
design	low	high	low	low	medium
mitigation	low	medium	medium	medium	medium
Score	**23**	**36**	**29**	**29**	**34**

Metrics: Operations

	Percent of extreme weather days vs. percent of normal days with service delays and cancellations	Percent of extreme weather days vs. percent of normal days with interruptions in telecommuni-cations	Percent of extreme weather days vs. percent of normal days with power outages and catenary line complications	Mean Distance Between Failure (MDBF) for buses by temperature and geography	Number of rail kinks/ buckling by temperature and by heat island areas
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	high	medium	medium	medium	high
severity	high	high	high	high	high
equity	medium	medium	medium	high	medium
feasibility	medium	medium	medium	medium	medium
cost * (points reversed)	medium	medium	medium	medium	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	high	medium	medium	high	medium
climate	high	high	high	high	high
visibility	medium	low	medium	high	medium
Participa-tion and governance	low	low	low	medium	low
design	medium	medium	medium	medium	medium
mitigation	low	none	low	medum	low
Score	**36**	**31**	**33**	**39**	**35**

Metrics: Operations

	Number of injuries/ medical emergencies to workers and riders by temperature and rainfall
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)	
criticality	medium
severity	high
equity	high
feasibility	medium
cost * (points reversed)	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)	
best practice	medium
climate	high
visibility	medium
Participation and governance	medium
design	medium
mitigation	low
Score	**37**

Metrics: Operations

	Percent insurance premium or bond rates spread for operations/ construction that are vulnerable to climate change	Are the costs of severe weather events being tracked (for federal disaster aid or otherwise) Y/N?	Is there a cost code associated with extreme weather so employees can mark down overtime, repairs etc as weather/ climate related Y/N?	What is the extra cost of extreme weather vs a baseline in $ and as percent of operating budget?	Loss in revenues from lower ridership on extreme weather days
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	high	medium	medium	medium	low
severity	high	high	high	high	medium
equity	low	low	medium	medium	medium
feasibility	medium	medium	medium	medium	high
cost * (points reversed)	medium	medium	high	high	low
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	low	medium	medium	medium	low
climate	medium	medium	medium	medium	medium
visibility	medium	high	medium	medium	medium
Participation and gover-nance	medium	medium	high	medium	medium
design	high	medium	low	low	medium
mitigation	medium	medium	medium	medium	none
Score	**34**	**33**	**33**	**31**	**31**

Metrics: Operations

	Percent increase in repair and replacement costs from accelerated reduction in state of good repair due to wear of extreme weather	Are savings from adaptation being measured/ calculated Y/N?	Percent savings for comparable extreme weather events with adaptation vs. without adaptation
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)			
criticality	medium	medium	medium
severity	medium	medium	medium
equity	low	low	low
feasibility	high	medium	medium
cost * (points reversed)	medium	low	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)			
best practice	medium	medium	low
climate			\
visibility	medium	medium	medium
Participation and governance	low	medium	low
design	high	low	medium
mitigation	medium	high	medium
Score	**30**	**30**	**26**

Metrics: Operations

	Does agency have a climate change preparedness team Y/N?	Percent of relevant divisions/ department actively represented on team	Percent of team participants authorized to make changes recommended by team in the adaptation planning process.	Number of technical advisors and members of the broader community included in team	Does agency collaborate with partner agencies, jurisdictions and organizations on climate adaptation Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	high	medium	high	low	low
severity	medium	low	low	low	low
equity	low	medium	medium	high	medium
feasibility	high	high	medium	high	high
cost * (points reversed)	medium	low	low	low	low
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	medium	low	medium	medium	medium
climate	medium	low	low	medium	medium
visibility	medium	medium	low	high	high
Participation and gover-nance	high	high	high	high	high
design	low	medium	medium	low	low
mitigation	medium	low	medium	medium	low
Score	**32**	**32**	**33**	**35**	**32**

Metrics: Adaptation

	Number of memoranda of understanding with partners	Number of other collaborations	Does agency use utilize the same climate projections/ models as partners Y/N?	Has agency identified mechanism for inter-agency coordination in place for other purposes that could be expanded to target climate change adaptation Y/N
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)				
criticality	low	low	medium	low
severity	none	low	medium	none
equity	medium	medium	none	low
feasibility	high	high	medium	medium
cost * (points reversed)	low	low	low	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)				
best practice	low	medium	low	low
climate	low	low	high	low
visibility	medium	medium	low	medium
Participation and governance	high	high	medium	high
design	low	low	none	low
mitigation	medium	medium	low	low
Score	**28**	**31**	**26**	**21**

Metrics: Planning

	Do agency design standards consider climate adaptation Y/N?	Percent of design and procurement standards for equipment and vehicles that require items to meet future climate conditions.	Has agency developed adaptation timeline for updating design and engineering standards Y/N?	Does agency utilize flood maps to determine facility design parameters such as drainage Y/N?	Percent of engieering standards that include tolerances for extreme weather events at the upper bounds of climate change projections
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	high	medium	medium	medium	medium
severity	medium	medium	medium	high	high
equity	medium	low	low	low	low
feasibility	medium	medium	high	high	medium
cost * (points reversed)	medium	medium	low	low	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	high	medium	medium	medium	medium
climate	medium	medium	low	medium	medium
visibility	low	low	low	low	low
Participa-tion and governance	medium	low	medium	low	low
design	high	high	high	medium	high
mitigation	medium	low	medium	low	low
Score	**35**	**28**	**29**	**33**	**30**

Metrics: Adaptation

	Does agency's asset management system measure heat and flood vulnerabilities for each asset Y/N?	Percent of assets considered to have significant vulnerability to heat	Percent of assets considered to have significant vulnerability to flooding	Has agency mapped urban heat islands across service area (or have access to map) Y/N?	Percents of above ground assets, critical assets, and vulnerable assets in urban heat islands
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	high	medium	medium	medium	high
severity	high	high	high	high	high
equity	medium	low	low	medium	medium
feasibility	medium	medium	medium	medium	medium
cost * (points reversed)	high	medium	medium	medium	high
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	medium	medium	medium	medium	low
climate	medium	medium	medium	medium	low
visibility	low	low	low	medium	low
Participation and governance	medium	low	low	low	low
design	medium	Medium	medium	low	medium
mitigation	medium	low	low	low	medium
Score	**33**	**29**	**29**	**31**	**30**

Metrics: Adaptation

	Percent of urban heat islands in service area with above average and majority transit dependent populations	Percent of Metro facilities and vehicles utilizing cool roofs	Percent foliage coverage at metro stations	Does agency have overheating standards for public transport facilities and rolling stock Y/N?	Percent of bus stops with shade
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	low	medium	medium	medium	low
severity	medium	medium	low	high	medium
equity	high	medium	low	medium	high
feasibility	medium	high	medium	high	medium
cost * (points reversed)	medium	low	low	medium	low
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	low	medium	low	medium	low
climate	medium	low	low	medium	low
visibility	medium	medium	medium	medium	high
Participation and gover-nance	medium	low	low	medium	medium
design	medium	high	medium	high	high
mitigation	low	high	medium	medium	low
Score	**30**	**36**	**27**	**37**	**33**

Metrics: Adaptation

	Percent of bus stops with seating	Percent of stations and stops with drinking water source	Does agency have timeline for adaptation efforts to reduce temperature at stops and stations Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)			
criticality	low	medium	medium
severity	low	medium	medium
equity	high	high	medium
feasibility	medium	medium	medium
cost * (points reversed)	low	low	low
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)			
best practice	none	low	low
climate	none	low	medium
visibility	low	medium	low
Participation and governance	low	low	medium
design	high	high	medium
mitigation	none	none	low
Score	**25**	**32**	**27**

Metrics: Adaptation

	Percent increase in power and fuel consumption on hot days vs. normal days	Percent of Metro's power generated from onsite renewable energy production	Percent of metro properties with on site energy generation
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)			
criticality	low	low	medium
severity	high	low	low
equity	none	low	low
feasibility	medium	high	high
cost * (points reversed)	medium	low	low
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)			
best practice	low	low	low
climate	medium	none	none
visibility	low	medium	high
Participation and governance	low	low	low
design	medium	medium	high
mitigation	high	high	high
Score	**26**	**27**	**31**

Metrics: Adaptation

	Percent of stations with capacity and efficiency of pumping and drainage systems to cope with flooding scenarios based on future precipitation and sea level rise projections	Percent difference in frequency of stormwater management equipment maintenance at facilities with high flood risk vs typical facility.	Percent of facilities with bioswales or other natural stormwater management systems	Percent of stormwater managed by agency that is managed by natural systems
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)				
criticality	medium	high	medium	low
severity	high	medium	medium	medium
equity	low	low	medium	low
feasibility	medium	medium	high	medium
cost * (points reversed)	medium	medium	low	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)				
best practice	high	medium	low	low
climate	medium	low	none	none
visibility	low	low	high	medium
Participation and governance	low	low	medium	low
design	high	high	high	medium
mitigation	none	none	low	medium
Score	**30**	**27**	**34**	**24**

Metrics: Adaptation

	Does agency have emergency procedures for high heat days, significant rain/ flooding events, and service interruptions Y/N?	Have these procedures been evaluated based on their performance in a real world weather emergencies Y/N?	Are there communication channels to alert public about weather-related delays, cancellations, etc Y/N?	Have these communication channels been tested and evaluated Y/N?	Percent of critical and vulnerable facilities with site specific emergency plans.
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	medium	medium	low	low	high
severity	high	high	medium	medium	medium
equity	medium	medium	high	medium	low
feasibility	medium	medium	medium	medium	medium
cost * (points reversed)	high	high	medium	medium	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	medium	low	medium	low	medium
climate	medium	medium	medium	low	low
visibility	medium	medium	high	high	medium
Participation and governance	high	medium	high	high	medium
design	medium	medium	medium	low	medium
mitigation	low	low	none	none	low
Score	**32**	**30**	**28**	**27**	**30**

Metrics: Adaptation

	Percent of rail stations, bus yards and other critical facilities with back- up generator capacity	Does agency have policies to modify construction schedules and labor practices to protect workers from high heat Y/N?	Does agency have designated evacuation routes for buses and emergency vehicles, including pick-up and drop-off points Y/N?	How many people can the agency evacuate in the event of a weather emergency	Have transit dependent and vulnerable populations been identified and/or mapped using established methods Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	high	low	medium	low	low
severity	medium	medium	high	high	medium
equity	low	high	high	high	high
feasibility	medium	high	medium	medium	medium
cost * (points reversed)	medium	medium	medium	medium	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	low	low	low	low	low
climate	low	medium	low	low	none
visibility	low	medium	high	high	medium
Participation and gover- nance	medium	medium	high	high	medium
design	high	high	Medium	medium	medium
mitigation	low	low	low	low	low
Score	**29**	**33**	**35**	**33**	**28**

Metrics: Adaptation

	Percent of rolling stock that is standing reserve available to cover broken down vehicles?	Percent of passengers who can be moved by alternative modes if one or more rail lines are closed by extreme weather?	Minimum level of back-up generator capacity to allow rail and bus operations for 24 and 48 hours.	Percent of stations and facilities with required level of back up generating capacity	Minimum level of compressed natural gas reserves to power 50% of bus fleet for one week
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	medium	medium	medium	medium	low
severity	medium	high	medium	medium	medium
equity	medium	high	medium	medium	medium
feasibility	high	medium	medium	medium	medium
cost * (points reversed)	medium	medium	medium	medium	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	medium	low	low	low	none
climate	low	medium	low	low	low
visibility	low	medium	low	low	low
Participation and governance	low	low	low	low	low
design	low	low	medium	medium	low
mitigation	low	low	medium	medium	low
Score	**29**	**32**	**29**	**29**	**23**

Metrics: Adaptation

	Percent of this reserve natural gas currently held and available by agency	Does agency have back up plan for failure of electric grid Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)		
criticality	low	medium
severity	medium	high
equity	medium	low
feasibility	medium	medium
cost * (points reversed)	medium	high
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)		
best practice	None	low
climate	Low	medium
visibility	Low	medium
Participation and governance	Low	high
design	Low	high
mitigation	low	medium
Score	**23**	**31**

Metrics: Riders

	Does agency have demographic analysis of its service area and ridership Y/N?	Has agency conducted a cumulative impact analysis of climate change on the public, especially on the most vulnerable populations Y/N?	Do agency's environmental impact assessments and/or related documents identify the potential for disproportionate impacts to impacts to minority, low income and disadvantaged populations from potential climate impacts Y/N	Percent of weather-re-lated service delays/ cancellations that occur in areas with above average transit-dependent populations.	Has agency surveyed riders on how their travel patterns change during high heat or heavy rain Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	medium	low	medium	medium	low
severity	low	medium	medium	high	medium
equity	high	high	high	high	high
feasibility	high	medium	medium	medium	medium
cost * (points reversed)	medium	high	high	medium	high
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	medium	low	low	low	low
climate	none	medium	medium	low	medium
visibility	medium	medium	medium	low	high
Participa-tion and gover-nance	medium	high	high	medium	medium
design	low	medium	medium	medium	medium
mitigation	medium	medium	medium	medium	medium
Score	**29**	**30**	**32**	**33**	**28**

Metrics: Riders

	Percent of residents living within walking distance of transit stations and/or high quality bus corridors	Percent of transit dependent service area population lives within convenient walk of train station or frequent bus route	Percentage of stations with clean mobility centers	Percent of stations with joint development plans, land use plans, and/or MOUs to increase density of housing and/or employment near station site
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)				
criticality	medium	medium	medium	medium
severity	low	low	none	low
equity	medium	high	medium	medium
feasibility	medium	medium	high	medium
cost * (points reversed)	low	low	low	medium
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)				
best practice	medium	medium	none	low
climate	low	low	none	low
visibility	medium	medium	high	high
Participation and governance	low	low	low	high
design	medium	medium	high	high
mitigation	medium	low	medium	high
Score	**30**	**31**	**29**	**30**

Metrics: Planning

	Existence of an ongoing and regularly convening team tasked with implementing climate adaptation plans. Y/N?	Number of staff tasked with implementing climate adaptation actions.	Percent of top priority climate adaptation recommen-dations/ actions from adopted plans implemented	Does agency publish regular reports or updates on climate adaptation efforts Y/N?	Does agency conduct regular planning updates to incorporate new climate change information and best practices into adaptation plans Y/N
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)					
criticality	high	medium	high	medium	high
severity	high	medium	high	medium	high
equity	medium	low	medium	medium	medium
feasibility	medium	high	medium	medium	medium
cost * (points reversed)	high	low	high	medium	high
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)					
best practice	high	medium	medium	medium	Medium
climate	medium	low	medium	medium	High
visibility	medium	medium	medium	high	low
Participa-tion and gover-nance	high	medium	high	medium	high
design	medium	low	high	medium	high
mitigation	high	medium	high	medium	medium
Score	**37**	**32**	**37**	**33**	**36**

Metrics: Planning

	Are climate vulnerabilities and the adaptation of assets tracked in agency's Environmental Management System and/or Asset Management System Y/N?	Percent progress in reducing vulnerabilities based on meta-analysis of climate adaptation indicators in EMS and/or asset management system.	Funding needed to implement priority adaptation efforts	Does agency have category for climate adaptation or category into which adaptation funding can fit Y/N?
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)				
criticality	high	high	high	low
severity	high	high	high	low
equity	medium	medium	medium	low
feasibility	medium	medium	medium	high
cost * (points reversed)	high	high	medium	low
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)				
best practice	high	low	low	low
climate	medium	medium	low	low
visibility	low	medium	medium	medium
Participation and governance	high	high	high	medium
design	high	high	medium	low
mitigation	medium	medium	medium	low
Score	**36**	**35**	**35**	**26**

Metrics: Planning

	Amount of money saved based on implemented preparedness action
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)	
criticality	medium
severity	medium
equity	medium
feasibility	medium
cost * (points reversed)	high
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)	
best practice	low
climate	low
visibility	medium
Participation and governance	medium
design	medium
mitigation	low
Score	**27**

Metrics: Riders

	Participation rates of public or advisory members in its internal climate change adaptation team or committee meetings	Records kept of outreach and numbers of stakeholders/ members of public engaged on climate adaptation in person and on-line Y/N	Number of stakeholders/ members of public engaged per year	Does agency request, collect, analyze and publish recom-mendations from public on climate change adaptation? Y/N
Core criteria (none = 0 pts, low = 2 pts, medium = 4 pts, high = 6 pts)				
criticality	low	low	medium	medium
severity	low	low	low	medium
equity	medium	high	medium	medium
feasibility	high	high	medium	medium
cost * (points reversed)	low	medium	medium	high
Multiple benefit criteria (none = 0 pts, low = 1 pt, medium = 2 pts, high = 3 pts)				
best practice	low	low	medium	low
climate	medium	low	low	low
visibility	medium	low	high	high
Participation and governance	high	medium	medium	high
design	low	none	low	medium
mitigation	medium	none	low	low
Score	**31**	**25**	**28**	**29**

APPENDIX 2: LITERATURE REVIEW

A review of the literature found that the most relevant information was contained in reports on climate adaptation efforts and pilot projects by transit agencies and large cities with mass transit systems in the United States and abroad. Because climate adaptation is a relatively new field and transit operators are just beginning to focus on the task, there are a relatively small number of directly applicable studies and plans. UEPI also reviewed literature on climate adaptation focusing on infrastructure, public health, and community engagement, which contained some recommendations that may be relevant to Metro's climate adaptation plans and processes.

This appendix summarizes the results of the literature reviews. Numbers in the table of metrics derived from the literature correspond to the list of documents in the bibliography.

I. List of Metrics Suggested by Literature Review

Metric and/or adaptation action	Suggested by *
Evaluating adaptive capacity	
Regulatory and institutional tools (such as policy processes) for adapting to climate change **and** barriers to accommodating changes in climate have been identified, such as requiring regulations and design standards to be based on historic climate conditions.	1, 2

• Have complete range of implementation tools (authority and/or avenues over which an organization has control or influence in policy, planning and infrastructure) that Metro possesses been identified Y/N?
  • Percent that include climate concerns
  • Have major barriers to incorporating climate adaptation into implementation processes/ tools been identified Y/N?
	1

Mapping vulnerabilities: climate, operations, finances and service. Climate change adaptation plans must go beyond broad generalizations of climate change impacts to transit infrastructure and operations by determining what impacts are most likely to occur, and how can levels of risk associated with the impacts be estimated. Furthermore, Non-climate change related factors that might influence climate change adaptations plans should be tracked as well. These include socioeconomic and demographic factors, and federal, state and local adaptation policies.	
*number corresponds to bibliography entry.	

Metric and/or adaptation action	Suggested by *

• Has a vulnerability assessment been conducted to identify the range of current and expected stresses on operations and system. Y/N?
  • Critical assets identified Y/N?
  • Percent of critical assets assessed?
  • Percent of all stations and lines assessed?
  • Most vulnerable assets identified Y/N
  • Impacts on riders analyzed Y/N?
  • Overlay of most vulnerable areas and assets with transit dependent and low-income populations Y/N?
  • Adaptation actions prioritized Y/N?
	1, 3, 4, 5, 6, 25,27, 28, 29

Climate modeling and weather monitoring
• Is a regional climate model (RCM) available to better determine locali impacts of climate change. Y/N?
  • Percent of service area covered by regional climate model
  • what is 'resolution' of RCM? (size of grid squares)
  • Is there a record of historical weather patterns for the service area Y/N?
  • Percent of service area covered by weather records
  • how many years do records go back?
  • Is there capacity to monitor weather and temperature conditions in real time at key locations in service area Y/N?
  • Number of real time monitoring stations
  • Ratio of monitoring stations/ service area in square miles
  • Percent of key assets with on site monitoring
	2, 4, 7, 8, 25

*number corresponds to bibliography entry.	

Metric and/or adaptation action	Suggested by *

Operations and service
• Percent of extreme weather days vs. percent of normal days with interruptions in telecommunications
  • Percent of extreme weather days vs. percent of normal days with service delays and cancellations
  • Percent of extreme weather days vs. percent of normal days with power outages and catenary line complications
  • Mean Distance Between Failure (MDBF) for buses by temperature and geography
  • Number of rail kinks/ buckling by temperature and by heat island areas
  • Number of injuries/ medical emergencies to workers and riders by temperature and rainfall
	6, 9, 10, 12, 25, 27, 29, 30

Finances
• Percent insurance premium or bond rates spread for operations/ construction that are vulnerable to climate change Y/N?
• Are the costs of severe weather events being tracked (for federal disaster aid or otherwise) Y/N?
  • Is there a cost code associated with extreme weather so employees can mark down overtime, repairs etc as weather/ climate related Y/N?
  • What is the extra cost of extreme weather vs a baseline in $ and as percent of operating budget?
  • Loss in revenues from lower ridership on extreme weather days
  • Percent increase in repair and replacement costs from accelerated reduction in state of good repair due to wear of extreme weather
• Are savings from adaptation being measured/ calculated Y/N?
  • Percent savings for comparable extreme weather events with adaptation vs. without adaptation
	2, 27, 29, 30

Coordinating activities across departments, jurisdictions and levels of government How well your government and community responds to the consequences of climate change may not only depend on the preparedness of an individual department, but also on numerous, cumulative actions across departments, divisions and programs.	
*number corresponds to bibliography entry.	

Metric and/or adaptation action	Suggested by *
Does agency have a climate change preparedness team Y/N? • Percent of relevant divisions/ department actively represented on team • Percent of team participants authorized to make changes recommended by team in the adaptation planning process. • Number of technical advisors (external scientific advisors) and members of the broader community (non-governmental organizations, businesses, other jurisdictional agencies and informal community leaders) included in team	4, 8
Does agency collaborate with partner agencies, jurisdictions and organizations on climate adaptation Y/N? • Number of memoranda of understanding with partners • Number of other collaborations • does agency use utilize the same climate projections/ models as partners Y/N? • Has agency identified mechanism for inter-agency coordination in place for other purposes that could be expanded to target climate change adaptation Y/N	1, 4, 13
Design issues and standards Climate change will require building infrastructure beyond current specifications, as well as updating design standards. Transportation engineering must focus on how environmental conditions over a longer timeframe could affect engineering design should occur, and in particular, whether current design standards and principles are adequate for infrastructure that could potentially be exposed to a wider range of weather extremes.	
Infrastructure designs based on climate variables and impacts expected at date of implementation and beyond. • Percent of engineering standards that include tolerances for extreme weather events at the upper bounds of climate change projections • Percent of design and procurement standards for equipment and vehicles that require items to meet future climate conditions. • Has agency developed adaptation timeline for updating design and engineering standards Y/N?	4, 10, 12, 14, 15, 20, 25, 28
Infrastructure siting • Does agency utilize flood maps to determine facility design parameters such as drainage Y/N?.	7, 10,
*number corresponds to bibliography entry.	

Metric and/or adaptation action	Suggested by *
Infrastructure adaptation Transportation Research Board (TRC, 2008, p 193): "state and local governments and private infrastructure providers should incorporate climate change into their long-term capital improvement plans, facility designs, maintenance practices, operations, and emergency response plans.'	

Asset management
• Does agency's asset management system measure heat and flood vulnerabilities for each asset Y/N?
  • Percent of assets considered to have significant vulnerability to heat
  • Percent of assets considered to have significant vulnerability to flooding
	4, 7, 17, 20

Reduce heat impacts on facilities, building materials, users and rolling stock:
• Has agency mapped urban heat islands across service area (or have access to map) Y/N?
  • Percent of above ground assets in urban heat islands
  • Percent of critical assets in urban heat islands
  • Percent of most vulnerable assets in urban heat islands
  • Percent of urban heat islands in service area with above average and majority transit dependent populations
• Percent of Metro facilities and vehicles utilizing cool roofs (roofs constructed with high-albedo materials that reflect and emit heat, thus reducing solar energy absorption).
• Percent foliage coverage at metro stations
• does agency have overheating standards for public transport facilities and rolling stock Y/N?
• Percent of bus stops with shade
• Percent of bus stops with seating
• Percent of stations and stops with drinking water source
• Does agency have timeline for adaptation efforts to reduce temperatures Y/N?
	3, 21, 23, 25, 29

Identify energy demands & generation opportunities • Percent increase in power and fuel consumption on hot days vs. normal days • Percent of Metro's power generated from onsite renewable energy production (solar, wind, geothermal, biomass etc) • Percent of metro properties with on site energy generation)	20, 24, 29
*number corresponds to bibliography entry.	

Metric and/or adaptation action	Suggested by *
Reduce precipitation impacts on facilities, building materials and rolling stock, • Percent of stations with capacity and efficiency of pumping and drainage systems to cope with flooding scenarios based on future precipitation and sea level rise projections • Percent difference in frequency of stormwater management equipment maintenance at facilities with high flood risk vs typical facility. • Percent of facilities with bioswales or other natural stormwater management systems • Percent of stormwater managed by agency that is managed by natural systems	3, 8, 21, 24, 25
Emergency preparedness	
Procedures and plans • Does agency have emergency procedures for high heat days, significant rain/ flooding events, and service interruptions Y/N? • Have these procedures been evaluated based on their performance in a real world weather emergencies Y/N? • Are there communication channels to alert public about weather-related delays, cancellations, etc Y/N? • Have these communication channels been tested and evaluated Y/N? • Percent of critical and vulnerable facilities with site specific emergency plans. • Percent of rail stations, bus yards and other critical facilities with back- up generator capacity • Does agency have policies to modify construction schedules and labor practices to protect workers from high heat Y/N?	1, 2, 25
System capacity • Percent of rolling stock that is standing reserve available to cover broken down vehicles? • Percent of passengers who can be moved by alternative modes if one or more rail lines are closed by extreme weather? • Minimum level of back-up generator capacity to allow rail and bus operations for 24 and 48 hours. • Percent of stations and facilities with required level of back up generating capacity • Minimum level of compressed natural gas reserves to power 50% of bus fleet for one week • Percent of this reserve natural gas currently held and available by agency • Does agency have back up plan for failure of electric grid Y/N?	3
*number corresponds to bibliography entry.	

Metric and/or adaptation action	Suggested by *
Transit's role in society-wide emergency preparedness • Does agency have designated evacuation routes for buses and emergency vehicles, including pick-up and drop-off points Y/N? • How many people can the agency evacuate in the event of a weather emergency • Have transit dependent and vulnerable populations been identified and/or mapped using established methods Y/N? [see Los Angeles County Operational Area (LACOA) Specific Needs Awareness Plan (SNAP)] Y/N?	22, 26, 27,
Transit, land use and vulnerable populations	
Prioritize adaptation measures in high-use, high need areas. • Does agency have demographic analysis of its service area and ridership Y/N? • Has agency conducted a cumulative impact analysis of climate change on the public, especially on the most vulnerable populations Y/N? • Do agency's environmental impact assessments and/or related documents identify the potential for disproportionate impacts to impacts to minority, low income and disadvantaged populations from potential climate impacts Y/N • Has agency surveyed riders on how their travel patterns change during high heat or heavy rain Y/N? • Percent of increased service delays/ cancellations attributable to weather that occur in areas with above average transit-dependent populations.	8, 9, 11, 16, 27
Encourage land uses, joint use development and last mile access so that more residents live near transit • Percent of residents living within walking distance of transit stations and/or high quality bus corridors • Percent of transit-dependent service area population lives within convenient walk of train station or frequent bus route • Percentage of stations with clean mobility centers • Percent of stations with joint development plans, land use plans, and/or MOUs to increase density of housing and/or employment near station site	11, 24
Performance monitoring Measuring progress of climate adaptation efforts should happen at multiple levels and for multiple audiences, including the internal team as well as with partners and the public.	
*number corresponds to bibliography entry.	

Metric and/or adaptation action	Suggested by *
Assess the "mainstreaming" of climate adaptation into decision making in priority planning areas. • Existence of an ongoing and regularly convening team tasked with implementing climate adaptation plans. Y/N? • Number of staff tasked with implementing climate adaptation actions. • Percent of top priority climate adaptation recommendations/ actions from adopted plans implemented • Does agency have guidelines on how to integrate new or updated information on climate change vulnerability, risk and preparedness into decision making Y/N? • Are climate vulnerabilities and the adaptation of assets tracked in agency's Environmental Management System and/or Asset Management System Y/N? • Percent progress in reducing vulnerabilities based on meta-analysis of climate adaptation indicators in EMS and/or asset management system. • Does agency publish regular reports or updates on climate adaptation efforts Y/N?	2, 4, 8, 18, 28, 29
Financial feasibility—climate adaptation budgeting • Funding needed to implement priority adaptation efforts • Percent of this funding provided in annual budget. • Does agency capital and/or operating budget have category for climate adaptation or category into which adaptation funding can fit Y/N? • Amount of money saved based on implemented preparedness actio	1, 8, 29
Evaluate community partnerships and stakeholder engagements in climate adaptation process. • Participation rates of public or advisory members in its internal climate change adaptation team or committee meetings • Records kept of outreach and numbers of stakeholders/ members of public engaged on climate adaptation in person and on-line Y/N • Number of stakeholders/ members of public engaged per year • Does agency request, collect, analyze and publish recommendations from public on climate change adaptation? Y/N	1, 18, 22
Regularly review assumptions and performance measurements in regards to climate change preparedness and adaptation. • Does agency conduct regular planning updates to incorporate new climate change information and best practices into adaptation plans Y/N	1, 8, 9, 28
*number corresponds to bibliography entry.	

LITERATURE REVIEW BIBLIOGRAPHY

1. "Preparing for Climate Change: A Guidebook for Local, Regional and State Governments". Prepared by the Climate Impacts Group and King County, Washington. 2007.

The guidebook is intended to assist local, regional, or state governments prepare for climate change. It lays out a process that includes scoping potential impacts on important social and economic sectors; involving the public; creating a planning team; conducting vulnerability and risk assessments; developing a vision and tools for a climate resilient community; creating a climate change preparedness plan; and developing and tracking measures of resilience.

2. Jacob, Klaus, and Reginald Blake, Radley Horton, Daniel Bader, Megan O'Grady. "Chapter 7: Indicators and monitoring". *New York City Panel on Climate Change 2010 Report,* Annals of the New York Academy of Sciences. 1196:1 (2010). 127-142.

This chapter contains recommendations for tracking and monitoring indicators to help the New York City region more effectively adapt to climate change. It suggests indicators related to climatic conditions, climate science, climate impacts, and adaptation activities, based on policy relevance, analytical soundness and measurability.

3. "Adapting to climate change: Lessons for London". London Climate Change Partnership. Greater London Authority, London. 2006.

This review examines eighteen case studies of climate adaptation measures to understand how cities within Europe, the United States, Japan, China and Australia are addressing three climate risks—flooding, high temperatures and limited water resources—with a focus on how such measures could potentially benefit London. The general conclusions and key recommendations include identifying the need for city-wide planning, as well as partnerships between different organizations, and across geographic boundaries; that climate change needs to be considered in short, medium and long-range decision-making, recognizing the interactions between different measures; that holistic, integrated thinking is required to manage climate risks most effectively; and that the opportunities for "climate-proofing" new developments are easier to realize, and must be driven through the planning process.

4. "Mainstreaming Climate Change Adaptation Strategies Into New York State Department of Transportation's Operations: Final Report". Prepared for the New York State Department of Transportation by the Center for Climate Systems Research. 2011.

This study identifies climate change adaptation strategies and best practices, and recommends ways of mainstreaming them into planned actions, including legislation, policies, programs and projects in all areas and at all levels within the New York State Department of Transportation (NYSDOT) in light of climate change impacts and vulnerabilities in NYS. The study's recommendations are presented in eleven categories: planning policies and guidelines, organization and management, inter- and intra-agency coordination, regional aspects of adaptation planning, vulnerability inventories, design issues, infrastructure adaptations, monitoring and assessment, training needs, communications, and research needs.

5. "Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation". FTA Report No. 0001, Federal Transit Administration. 2011.

This report discusses potential climate change impacts on public transit and adaptation strategies to help transit adapt to climate change. It considers precipitation, temperature, sea level rise, severe weather and combined impacts. The report provides best practices and case studies from domestic and foreign transit agencies on how to assess vulnerabilities, develop adaptation strategies, and implement strategies.

6. Metro Internal Survey of Operations Employees. 2011 or 2012?

Los Angeles Metro surveyed employees with a range of operational responsibilities on impacts they anticipated from climate change and possible mitigation actions that could be taken to address these impacts. The survey covered heavy rain, high temperatures, blackouts or brownouts and windstorms or wind gusts.

7. Walker, Lindsay, and Miguel A. Figliozzi, Ashley R, Haire, and John MacArthurt. "Identifying Surface Transportation Vulnerabilities and Risk Assessment Opportunities Under Climate Change". *Transportation Research Record: Journal of the Transportation Research Board, No. 244,* Transportation Research Board of the National Academies. (2011) 41-49.

In conjunction with the transportation asset management approach described by Meyer et. al, geographic information systems can be utilized to assess climate change vulnerabilities in multimodal transportation system. This report uses Portland, Oregon as its case study

8. "2012 King County Strategic Climate Action Plan". Prepared by King County, Washington. 2012.

This strategic plan is a framework for King County's mitigation and adaptation plans and strategies. It includes emission reduction strategies, adaptation plans, and public outreach and collaboration plans.

9. Zimmerman, Rae, and Craig Faris, "Chapter 4: Infrastructure impacts and adaptation challenges". *New York City Panel on Climate Change 2010 Report,* Annals of the New York Academy of Sciences. 1196:1 (2010). 63-86.

Zimmerman and Faris discuss the challenges to climate change adaptation in major urban infrastructure sectors, focusing on New York, and draw lessons from adaptation efforts underway in other large metropolitan regions. They argue that understanding the characteristics of a city's infrastructure that make it particularly vulnerable to the impacts of climate change is a critical foundation for understanding the severity of the impacts and the means for adaptation.

10. Meyer, Michael D, and Brent Weigel. "Climate Change and Transportation Engineering: Preparing for a Sustainable Future", *Journal of Transportation Engineering.* 137:6 (2011). 393-403.

This paper explores how transportation infrastructure could be impacted by climate change. It recommends an adaptive systems management approach to help anticipate likely climate changes, identify vulnerabilities in the transportation system, and assess different strategies for mitigating potential impacts.

11. California Environmental Health Tracking Program, "ASTHO Climate Change Population Vulnerability Screening Tool." California Department of Public Health. 2012.

This report used an Environmental Justice Screening Methodology (EJSM) to assess vulnerability to climate change impacts in different census tracts in Fresno and Los Angeles Counties. Indicators include access to transit. By describing the process, the report suggests how jurisdictions and agencies can identify populations and areas that are particularly vulnerable to the impacts of climate change.

12. Nolte, Roland, and Christian Kamburow, Johannes Rupp. "Adaptation of Railway Infrastructure to Climate Change". Institute for Future Studies and Technology Assessment. 2011.

This report suggests managing weather and climate related natural hazards to avoid or minimize damage to railway infrastructure. It suggests a process consisting of gathering weather Information; documenting past weather events; mapping natural hazards; monitoring infrastructure status; mapping vulnerability; assessing risk; analyzing regional climate models and risks; and adopting adaptation strategies.

3. "Climate change and London's transport systems: Summary Report". London Climate Change Partnership. Greater London Authority, London. 2005.

This report evaluates the potential risks of climate change to London's transport systems and recommends how the risks identified can be incorporated into transport management strategies. The report includes case studies of station flooding, infrastructure damage from high temperatures, and customer comfort in underground stations.

14. Neumann, James. "Adaptation to Climate Change: Revisiting Infrastructure Norms". *Issue Brief*, Resources for the Future (2009). 9-15.

Neumann provides three recommended changes to current federal infrastructural policies to better prepare public infrastructure, which has immense value as both a capital asset and an essential element to a productive economy, for the stress of climate change: incorporating climate forecasts more effectively in infrastructure capital and maintenance decisions; reconsidering the location of new and updated infrastructure investments; and updating infrastructure design standards

15. "Adapting Transportation to the Impacts of Climate Change: State of the Practice 2011". *Transportation Research Circular, E-C152*. Transportation Research Board of the National Academies. 2011.

The articles in this circular address a range of climate adaptation issues facing state departments of transportation and metropolitan planning organizations. It discusses adaptation strategies that have been implemented in the United States and United Kingdom and the need for collaboration and information collection.

16. "Light Rail Design Criteria, Chapter 2: Environmental". Utah Transit Authority. 2007.

These design criteria include a requirement to consider environmental justice impacts.

17. Meyer, Michael et. al. "Transportation Asset Management Systems and Climate Change: An Adaptive Systems Management Approach". ***Transportation Research Record: Journal of the Transportation Research Board.*** **2160-1 (2010)**

This paper examines how transportation asset management systems can incorporate the anticipated effects of climate change into transportation agencies infrastructure preservation and asset management processes. A case study of highways is provided but the approach may be applicable to transit operations as well.

18. Gudmundsson, Henrik, and Mary Lawler, Maria Figueroa, Miles Tight. "How Does Transport Policy Cope with Climate Challenges? Experiences from the UK and Other European Countries."

This paper examines how sustainable transport policy frameworks in the Netherlands, Sweden, and the United Kingdom deal with climate change. There is a particular focus on monitoring and implementation.

19. ***Journal of Transportation Engineering*****. 137:6 (2011). 383-392.**

This paper examines transportation policy responses to climate change in the Netherlands, Sweden, and the U.K., in particular highlighting the U.K.'s government-wide system of goal-setting and performance measurement; goals are set alongside the annual spending review of the Department of Transportation and negotiated with the treasury such that the level of resources available is determined in a coordinated way.

20. Los Angeles World Airports. Sustainable Airport Planning, Design and Construction Guidelines for Implementation on All Airport Projects. Version 5.0 • February 2010

LAWA's guidelines for sustainable airport planning, design and construction cover climate adaptation planning for increased temperature, severe weather, sea level rise and storm surge, and ecosystem changes. The Guidelines include a point based system with up to three points available for each of the four climate change impacts analyzed. Includes actions and targets, technical approaches, benefits, and suggested documentation.

21. Center for Clean Air Policy. The Value of Green Infrastructure for Urban Climate Adaptation. 2011

This report discusses the potential of green infrastructure as climate adaptation strategies. It covers green, blue, and white roofs; permeable surfaces; and green alleys and urban forestry. The report provides cost estimates for different forms of green infrastructure as well as describing and quantifying such benefits as better management of storm-water runoff, storm-surge protection, and reduced ambient temperatures and urban heat island effects.

22. Pacific Institute and California Energy Commission's California Climate Change Center. Community-based Climate Adaptation Planning: Case Study of Oakland, California. July 2012

This report analyzes climate impacts, vulnerabilities, and adaptation options in Oakland, California. The goal is to inform the development of a "comprehensive and equitable climate adaptation plan effort." The report features best practices on engaging the community in climate adaptation planning and in addressing the needs of vulnerable populations.

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This assessment considers the vulnerability of eight key economic and social sectors, including the Built Environment and Infrastructure, of which public transit is a part. The assessment also recommends potential adaptation actions for these sectors.

24. Los Angeles County Metropolitan Transportation Authority. Metro Rail Design Criteria. Environmental Considerations. 2012.

The environmental section of these design criteria are intended to minimize adverse adverse effects to the environment from rail system construction and operation. The criteria cover such impacts as energy, water, land use, noise, and vibration.

25. Los Angeles County Metropolitan Transportation Authority. Climate Action and Adaptation Plan. Environmental Considerations. 2012.

This plan includes strategies for reducing greenhouse gas emissions from Metro operations and for adapting to higher temperatures and more severe weather and precipitation. The climate adaptation section of the plan summarizes weather records and anticipated changes in climate for Los Angeles County; assesses the criticality and vulnerability of assets to climate change; and recommends adaptation actions.

26. "Special Report 294: The Role of Transit in Emergency Evacuation". Prepared by the Transit Research Board. 2008.

Special Report 294 was requested by Congress and funded by the Federal Transit Administration and the Transit Cooperative Research Program to investigate the role of transit in emergency planning and emergency operating procedures, in the wake of September 11 and Hurricane Katrina. It contains a literature review and assessment of publicly available emergency response and evacuation plans for 38 large urbanized areas, and five in-depth case studies, including the Los Angeles urban area. The report finds that the majority of such plans are only partially sufficient in describing in specific and measurable terms how a major evacuation could be conducted successfully, and even fewer focus on the vitally important role that transit can play in the four components of emergency planning: mitigation, preparedness (decision making structures), response, and recovery.

27. Southeastern Pennsylvania Transportation Authority, ICF International, and the Delaware Valley Regional Planning Commission. A Vulnerability & Risk Assessment of SEPTA's Manayunk/Norristown Line. Presentation to FTA Peer Exchange Webinar. November 2012.

This pilot project is analyzing a light rail line for historical impacts of extreme weather; projecting future impacts from a changing climate; and identifying and prioritizing adaptation actions for the agency and line.

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This pilot project is studying how a transit agency can use an enterprise asset management system to monitor climate changes and help identify response strategies.

29. Chicago Transit Authority and TransSystems Consulting. An Integrated Approach to Climate Adaptation for Transit Assets in Chicago. Presentation to FTA Peer Exchange Webinar. November 2012.

This update describes progress made on CTA's pilot project to survey vulnerabilities of twenty to thirty types of assets; analyze three types of risk in detail; and develop long-term strategies to mainstream climate adaptation into asset management, operations planning and other standard business practices.

30. Transportation Research Board. State of Good Repair: Prioritizing the Rehabilitation and Replacement of Existing Capital Assets and Evaluating the Implications for Transit. TCRP Report 157. 2012.

This report presents a framework for transit agencies to use for prioritizing capital asset rehabilitation and replacement decisions. The report includes equations and spreadsheets models for tracking and calculating state of good repair.